

4 January 1968

Materiel Test Procedure 5-2-542
White Sands Missile RangeU. S. ARMY TEST AND EVALUATION COMMAND
COMMON ENGINEERING TEST PROCEDURE

MISSILEBORNE HYDRAULIC POWER SUPPLIES

1. OBJECTIVE

The objective of the procedures outlined in this Materiel Test Procedure is to ascertain the power supply characteristics such as fuel consumption, power capability, regulation, and reliability. Proper evaluation can eliminate the power supplies which could cause failure of a missile flight.

2. BACKGROUND

Hydraulic power supplies, as used in conjunction with missileborne guidance and control systems, provide a source of motive power for use in positioning missile control mechanisms. In addition, a hydraulic power supply (hereafter referred to as power supply) may be used to actuate propulsion system valves, to drive hydraulic motor generator combinations, to drive cooling systems, or to provide auxiliary power for various miscellaneous mechanisms.

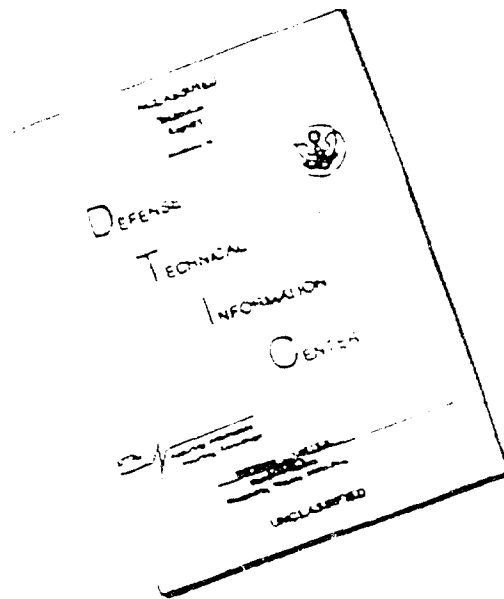
Engineers and other personnel actively engaged in the testing and evaluation of power supplies have developed, over a long period of time, procedures for testing. Properly used, these procedures can readily determine the acceptability of a power supply for an intended use. The power supply must adhere to government or the manufacturer's specifications to be accepted. (See Appendix A for additional Background information).

3. REQUIRED EQUIPMENT

- a. Centrifuges
- b. Flow meters
- c. Thermocouples
- d. Oscillographs
- e. Timers
- f. Heat exchanger
- g. Pressure transducers
- h. Globe valves
- i. Pressure switches
- j. Servo valves
- k. Function generators
- l. Vibration table
- m. Hydraulic tester
- n. Strain gauges
- o. Micrometers
- p. Photographic equipment

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4. REFERENCES

- A. AFM 52-31, Guided Missiles Fundamentals, 1950.
- B. Pippenger, John J., Fluid Power Controls, McGraw-Hill Book Company, Inc., New York, Toronto, and London, 1959.

5. SCOPE

5.1 SUMMARY

This MTP describes the procedures required to ascertain such hydraulic power supply characteristics as fuel consumption, power capability, regulation, and reliability in order to determine the applicability of a power supply to a given use.

The specific tests to be made are summarized below:

- a. Start Time Test - A test to determine the ability of the power supply to deliver full power within a specified time limit.
- b. Pressure Regulation Test - A test to determine the ability of the power supply to maintain a uniform pressure under dynamic and steady state load conditions.
- c. Steady State and Dynamic Power Capabilities Test - A test to determine if the power supply meets the power output requirements under various load conditions.
- d. Fuel Consumption and Nominal Onboard Run Time Test - A test to determine if the power supply meets the power output requirements under various load conditions.
- e. Operating Positions Test - A test to determine the operating characteristics of the power supply with the unit subjected acceleration in various attitudes.
- f. Resonant Spectrum Test - A test to determine power supply limitations created by vibrational stress.
- g. Valve Seal and Operating Limits Test - A test to ensure the absence of internal and external leakage at relief and check valves. In addition, the pressure at which the relief valve opens and closes is determined.
- h. Hydrostatic Test - A test to determine at what pressure, in excess of design operating pressures, yielding or permanent elongation of the accumulator shell occurs.
- i. Nominal Heat Rise Test - A test to measure the oil temperature rise that occurs when the power supply is operated for a period representative of the duration of a missile flight.
- j. Operating Life and Wear Resistance Test - A test to determine the usable life of the power supply during ground operating conditions. This is a destructive test and should be conducted on a spare unit.
- k. Overspeed and Burst Speed Test - A test to determine the conditions when the speed control mechanism fails. This is a destructive test and should be conducted on a spare unit.

5.2 LIMITATIONS

This MTP is limited in scope to those hydraulic power supplies which do not use the main propulsion system power takeoff as the prime mover. The procedures were intentionally made general to provide the broadest possible coverage for variations between power supplies. The procedures may be adapted as necessary to accommodate specific units.

The tests shall be performed in a laboratory under room ambient conditions unless applicable specifications direct otherwise. In the case where other environmental conditions are required, it will be necessary to obtain those MTP's or military documents (MIL-E-5272 or MIL-STD-810, USAF) that include the specifications for the subject requirements.

Various environments and conditions under which influence on performance and physical effects is determined are given in the MTP's covering the following:

- (1) Vibration tests
- (2) Mechanical shock testing of missile structures
- (3) Tactical Hazards and safety tests
- (4) Chamber environmental tests of missile and rocket systems
- (5) Combined structural environmental tests of missile and rocket systems

6. PROCEDURES

6.1 PREPARATION FOR TEST

a. Select test equipment having an accuracy of at least 10 times greater than that of the function to be measured.

b. Record the following information:

- 1) Nomenclature, serial number(s), and manufacturer's name of the test item(s).
- 2) Nomenclature, serial number, accuracy tolerances, calibration requirements, and last date calibrated of the test equipment selected for the tests.

c. Ensure that all test personnel are familiar with the required technical and operational characteristics of the item under test such as stipulated in Qualitative Materiel Requirements (QMR), Small Development Requirements (SDR), and Technical Characteristics (TC).

d. Review all instructional and specifications material issued with the test item by the manufacturer, contractor, or government, as well as reports of previous tests conducted on the same types of equipment, and familiarize all test personnel with the contents of such documents. These documents shall be kept readily available for reference.

e. Prepare record forms for systematic entry of data, chronology of test, and analysis in final evaluation.

f. Assure that qualified safety personnel maintain a continuous observation of the test item through the entire test period to include unsafe conditions or practices related to the use of the test item.

g. Consult all pertinent paragraph, table, and figure references, prior to commencing a particular test, to prevent risk of equipment damage or test failure through lack of instructions or understanding.

h. Whenever possible, conduct the same test on all hydraulic power supplies of a similar type with the same test configuration before proceeding to the next test. This practice will save time and will help in correlating the test results.

i. The test configuration used for a particular power supply should not be disturbed until all data have been recorded.

j. Determine the input and output requirements of the power supply to be evaluated.

k. Ascertain that the power supply physical characteristics are within the specified requirements. All defects shall be corrected before proceeding with the test.

NOTE: The actual missile components should be used as the load when conducting the tests. If this is not possible, a globe valve or servo valve shall be used.

6.2 TEST CONDUCT

CAUTION

If evidence of cavitation occurs i.e., erratic pressure, excessive vibration, and/or a crackling sound when conducting any of the tests listed in the MTP, stop the test immediately to avoid damaging the equipment. In addition, if the actual missile components are not used as the power supply load, a heat exchanger shall be used to prevent damage due to excessively high temperatures.

6.2.1 Start Time Test

a. Connect a pressure switch, a timer, and a heat exchanger to the power supply and load as shown in Figure 1.

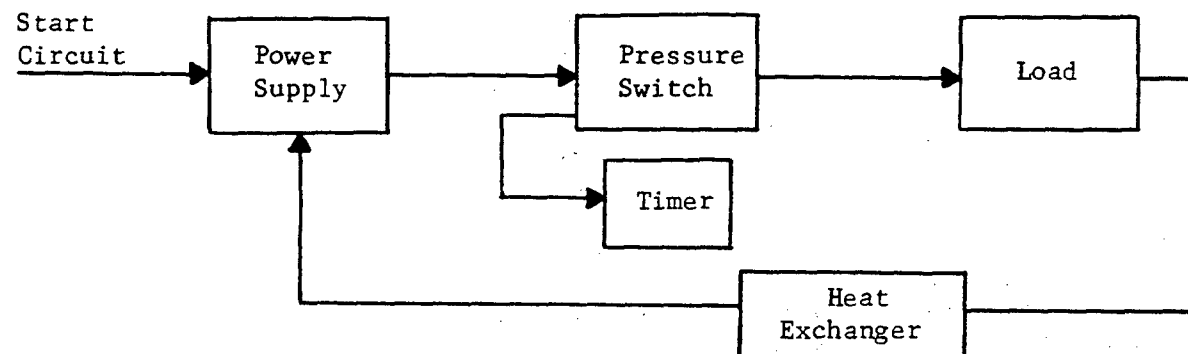


Figure 1. Typical Start Time Test Configuration

b. Start the power supply and the timer simultaneously. When the power supply reaches the specified operating pressure, the pressure switch will turn the timer off.

c. Record the timer indication on a suitable data form.

d. Repeat Steps (b) and (c) above, a total of 10 times.

6.2.2 Pressure Regulation Test

6.2.2.1 Steady State Demand

a. Connect a flow meter, a pressure transducer, an oscillograph, a heat exchanger, and a hand adjustable globe valve (load) to the power supply as shown in Figure 2.

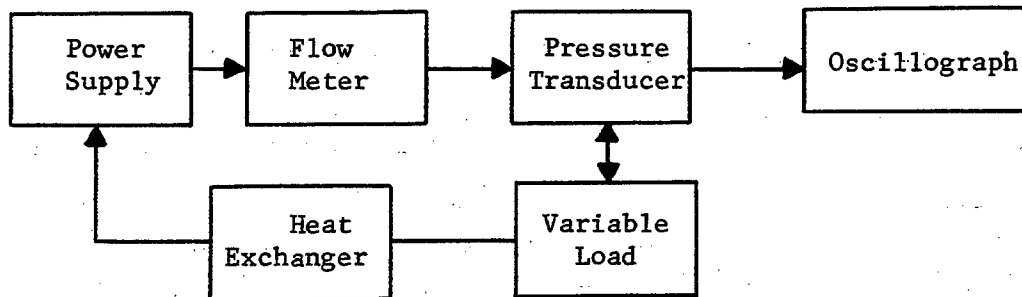


Figure 2. Typical Pressure Regulation Test Configuration

b. Start the power supply.

c. Open the globe valve and observe the flow meter to determine that the system is operating in the required flow range.

d. Adjust the globe valve to simulate various static load conditions and record the output pressure for each condition on the oscillograph.

6.2.2.2 Dynamic Demand

a. Replace the globe valve in the test configuration of 6.2.2.1 above, with an electrically operated servo valve as the power supply load. (A variable input to the servo valve is necessary to obtain step and ramp input conditions).

b. Start the power supply and operate the servo valve so that the flow meter indicates the system is operating in the required flow range.

c. Operate the servo valve so that it causes a sudden (step input) load change of approximately 30 percent of the power supply operating range.

d. Record the output pressure indicated on the oscillograph.

e. Operate the servo valve through the same range as in step (c) above, except vary the load gradually (ramp input).

f. Record the output pressure as in Step (d) above.

g. Disconnect the electrical input to the servo valve and connect a sine wave generator to the valve.

h. Choose a spectrum of frequencies through which to drive the servo valve that is representative of those expected in flight. (If possible, use the frequency range determined from an actual flight recording). Adjust the sine wave generator so that each frequency in turn is supplied as an input to the servo valve.

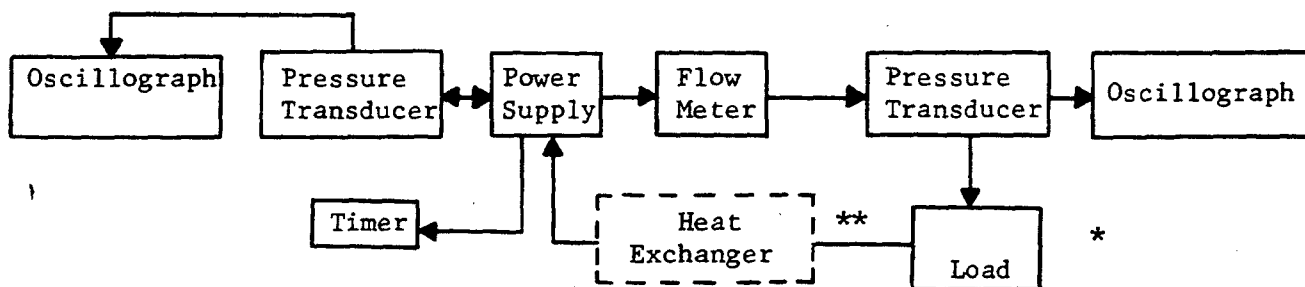
i. Record the output pressure indicated on the oscillograph for each frequency.

6.2.3 Steady State and Dynamic Power Capabilities Test

a. Repeat the tests described in paragraphs 6.2.2.1 and 6.2.2.2 except record both the pressure and rate of flow simultaneously. In addition, the power should be increased slightly above that expected in actual operation and the pressure and rate of flow again recorded.

6.2.4 Fuel Consumption and Nominal Onboard Run Time Test

a. Connect two pressure transducers, two oscillographs, a timer, and a flow meter to the power supply under test and its load as shown in Figure 3.



*If practicable, the power supply should drive the same missile components it would drive in flight.

**If a variable load is used, a heat exchanger must also be used to avoid damage to components.

Figure 3. Typical Fuel Consumption and Nominal Onboard Run Time Test Configuration.

- NOTES:
1. The pressure transducers and oscillographs should be connected one at the output and one at the input to the power supply pump to obtain indications of supply and back pressures, respectively.
 2. A full source of power is required for this test.

b. Beginning with a no load, full open valve flow condition, start the power supply, oscillograph, and timer simultaneously, and allow it to operate until the fuel supply is exhausted.

c. Record the following information on the two oscillographs:

- 1) Flow rate
- 2) Load condition
- 3) Back pressure
- 4) Supply pressure
- 5) Power supply operating time

d. Increase the load level in increments of 10-percent to include the maximum reasonable load, and repeat step (c) for each 10-percent increment.

6.2.5 Operating Positions Test

a. Connect a flow meter, pressure transducer, oscillograph, and heat exchanger to the power supply and its rated load as shown in Figure 2, and mount them on a centrifuge (connect the oscillograph through the slip-rings).

b. Align the rotating axis of the power supply pump in one of the seven relationships with the centrifuge acceleration axis shown in Figure 4.

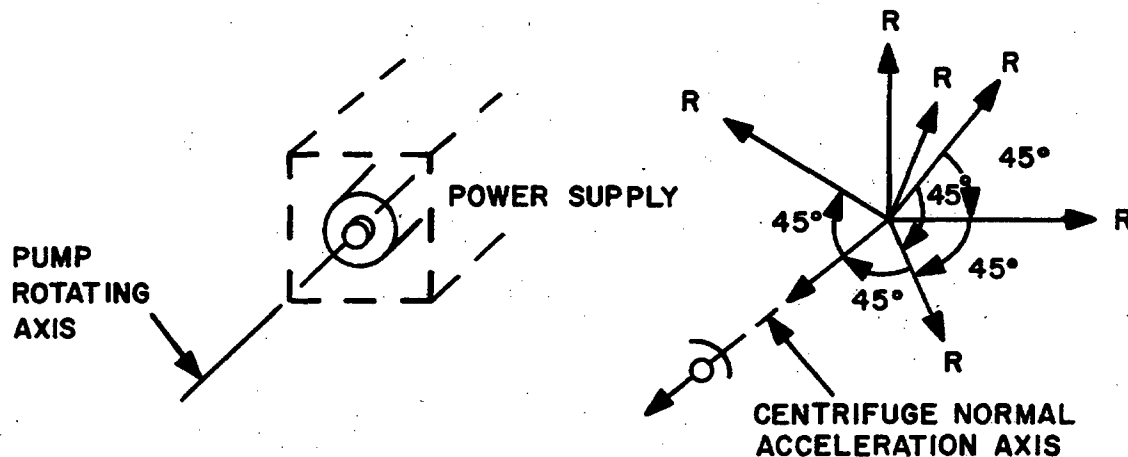


Figure 4. Axis Orientation for Position Testing.

c. Start the power supply, subject it to an acceleration of the same magnitude experienced during actual flight, and repeat the Pressure Regulation and Steady State and Dynamic Power Capabilities tests as described in paragraphs 6.2.2 and 6.2.3.

d. Repeat Step (c) above, with the power supply and associated monitoring equipment mounted on each of the other six axis orientations.

6.2.6 Resonant Spectrum Test

a. Connect a flow meter, a pressure transducer, an oscillograph, and a heat exchanger to the power supply and its rated load as shown in Figure 2, and mount the power supply and its associated monitoring equipment on a vibration table.

b. Conduct a Steady State and Dynamic Power Capabilities test as described in paragraph 6.2.3, while subjecting the test configuration to all vibrational frequencies normally expected to occur during a missile flight.

c. Record the resonant frequencies and amplitudes indicated on the oscillograph.

6.2.7 Valve Seal and Operating Limits Test

6.2.7.1 Internal Leakage

a. Connect two flow meters and an oscillograph to the power supply and its rated load as shown in Figure 5.

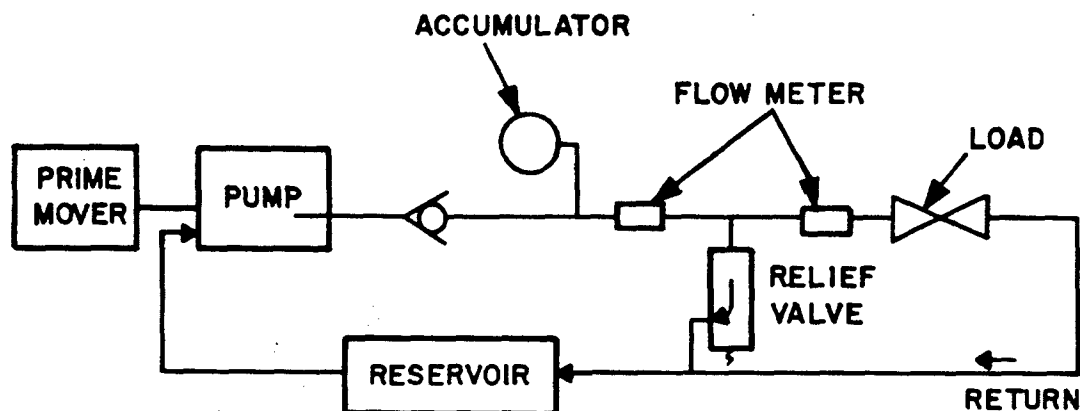


Figure 5. Typical Internal Leakage Test Configuration

b. Start the power supply and note the flow meter indications as recorded on the oscillograph.

c. Stop the unit and remove the flow meters and oscillograph connected above.

d. Connect an external power supply into the high pressure line, and connect a flow meter and oscillograph into the external power supply to indicate the total input flow.

e. Start the external power supply, apply pressure to the high pressure line, and note the flow meter indications.

6.2.7.2 External Leakage

a. Connect the power supply under test to its rated load, and start the unit.

b. Install a drip pan beneath the power supply and operate the unit for a period of time representative of an actual missile flight.

c. At the completion of the above operating period, stop the unit, accurately measure the amount of oil collected in the drip pan, and record on a suitable data form.

d. Repeat Steps (b) and (c) above, a minimum of 10 times.

6.2.7.3 Valve Operating Limits

a. Disconnect the relief valve from the power supply under test, and connect it to a hydraulic tester.

b. Starting with minimum pressure, operate the hydraulic tester to cause a gradual increase in the pressure until the relief valve opens.

- c. Record the pressure at which the relief valve opens.
- d. Operate the hydraulic tester to cause a gradual decrease in pressure until the relief valve reseats.
- e. Record the pressure at which the relief valve closes.

6.2.8 Hydrostatic Test

- a. Measure each valve with a micrometer and record measurements taken.
- b. Attach strain gauges to the supply and return lines, accumulator, reservoir, actuator, and servo transfer valve. Block the relief valve to prevent it from opening.
- c. Utilizing a hydraulic tester, subject all components of the power supply to oil pressures equal to the proof test limits as established by the manufacturer.
- d. Measure each valve with a micrometer and record any measurements of yielding of any component obtained from the strain gauges or by a post-test micrometer measurement of the valves.
- e. Check the manufacturer's specifications to determine if the accumulator burst pressure exceeds the stall out pressure of the power supply pump. If so, add a redundant relief valve to ensure safe operation of the power supply.

6.2.9 Nominal Heat Rise Test

- a. Install thermocouples in the power supply as shown in Figure 6.
- b. Connect the thermocouples to a multichannel recorder.

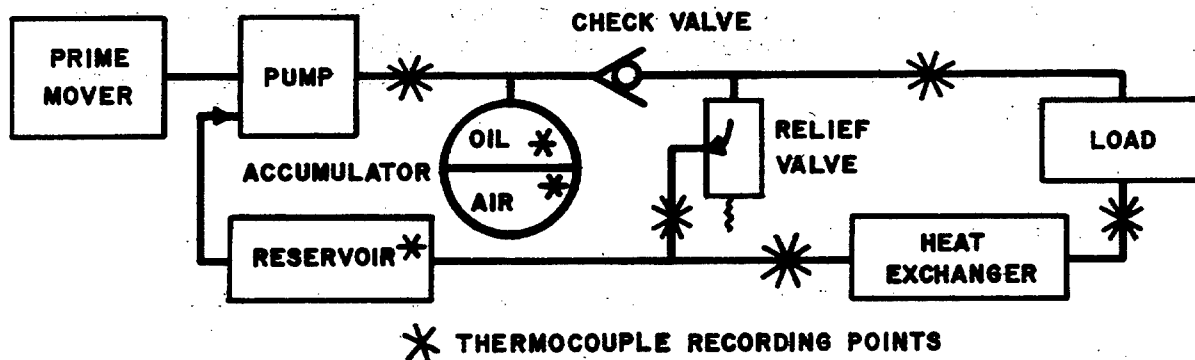


Figure 6. Typical Nominal Heat Rise Test Configuration

- c. Operate the power supply under the load conditions described in paragraphs 6.2.2 and 6.2.3 and record the temperature.
- d. Operate the power supply for a time representative of the time of a missile flight. While allowing the unit to cool down, record the temperature continuously until ambient temperature has been reached.

- e. Repeat Steps (c) and (d) above, a minimum of three times.

6.2.10 Operating Life and Wear Resistance Test

a. Determine, and record the number of times that the combination of tests outlined in paragraphs 6.2.1 through 6.2.4 can be conducted before the power supply output fails to meet the specifications.

b. Periodically during the endurance run outlined above, collect oil samples and subject them to spectrographic analysis to determine the change in percentage of entrained metal particles. In addition, perform particle distribution tests to ascertain the size of the contaminants produced, and record on a suitable data form.

c. After the power supply serviceability has dropped below acceptable standards, note and record the wear as indicated by the change in fit of mated moving parts.

6.2.11 Overspeed and Burst Speed Test

CAUTION

This is a dangerous test and must be conducted in an explosive test area.

a. Operate the power supply at the highest surge speed allowed by the specifications for a time representative of the duration of a missile flight.

b. If a failure in the power supply has not occurred, repeat Step (a) until a failure does occur.

c. Dismantle the unit and thoroughly inspect its components for damage. Record the observations and, if applicable, the failure point of the unit.

d. Obtain a turbine driven power supply and operate it at an increasing overspeed condition until the speed control mechanism fails.

e. Record the burst point (speed mechanism failure) of the turbine driven power supply.

6.3 TEST DATA

6.3.1 Preparation for Test

Data to be recorded prior to testing shall include but not be limited to:

- a) Nomenclature, serial number(s), and manufacturer's name of the test item(s)
- b) Nomenclature, serial number, accuracy tolerances, calibration requirements, and last date calibrated of the test equipment selected for the tests
- c) Deficiencies and discrepancies noted in equipment inspection prior to start of test
- d) Appropriate photographs of the test item and installation

6.3.2 Test Conduct

Data to be recorded in addition to specific instructions listed below for each individual subtest shall include:

- a. Photographs or motion pictures which will support test results or conclusions
- b. An engineering logbook containing in chronological order, pertinent remarks and observations which would aid in a subsequent analysis of the test data. This information may consist of temperature, humidity and other appropriate environmental data, or other descriptions of equipment or component, and functions and deficiencies.

6.3.2.1 Start Time Test

Record the times required for the power supply to reach the specified operating pressure.

6.3.2.2 Pressure Regulation Test

- a. Steady State Demand - Record output pressure for each static load condition.
- b. Dynamic Demand - Record output pressure with a step input. Record output pressure with a ramp input. Record output pressure for each frequency.

6.3.2.3 Steady State and Dynamic Power Capabilities Test

Record all data as in Pressure Regulation test except record the pressure and rate of flow simultaneously. Record pressure and rate of flow with the power level above normal.

6.3.2.4 Fuel Consumption and Nominal OnBoard Run Time Test

Record flow rate, load condition, back pressure, supply pressure, and power supply operating time for each load level condition.

6.3.2.5 Operating Positions Test

Record all data required by Pressure Regulation and Steady State and Dynamic Power Capabilities Tests with the power supply mounted on each acceleration axis.

6.3.2.6 Resonant Spectrum Test

Record all data required by the Steady State and Dynamic Power Capabilities test with the power supply mounted on a vibration table. Record resonant frequencies and amplitudes.

6.3.2.7 Valve Seal and Operating Limits Test

- a. Internal Leakage - Record flow meter indications. Record static and dynamic internal leakage.
- b. External Leakage - Record amounts of oil collected into a drip pan.
- c. Valve Operating Limits - Record pressure at which the relief valve opens. Record pressure at which the relief valve closes.

6.3.2.8 Hydrostatic Test

Record valve measurements prior to and after test. Record measurements of yielding obtained with strain gauges.

6.3.2.9 Nominal Heat Rise Test

Record oil temperatures for each condition of power supply operation.

6.3.2.10 Operating Life and Wear Resistance Test

Record operating life of the power supply. Record results of particle distribution tests and particle sizes. Record in narrative form, indications of wear supported by photographs with appropriate captions.

6.3.2.11 Overspeed and Burst Speed Test

Record damage to components and failure point of the power supply supported by photographs with appropriate captions. Record the burst point of the turbine driven power supply.

6.4 DATA REDUCTION AND PRESENTATION

6.4.1 Data Reduction

6.4.1.1 Start Time Test

Compute the average time required for the power supply to reach the specified operating pressure, and compare with specified tolerances. (The start time for most power supplies will be about 1 to 5 seconds, specified tolerances usually will not exceed 0.5 seconds).

6.4.1.2 Pressure Regulation Test

6.4.1.2.1 Steady State Demand

Check the oscillograph recordings for any oscillations lower than the resonant frequency of the component. Regulation is considered unsatisfactory if any of these are present.

6.4.1.2.2 Dynamic Demand

Examine the oscillograph recordings to ensure that the output pressures do not exceed the specified tolerances for either a step, ramp, or sinusoidal input to the power supply.

6.4.1.3 Steady State and Dynamic Power Capabilities Tests

Examine the oscillograph recordings to ensure that all of the oscillations are higher than the resonant frequency and that the output pressures for step, ramp, and sinusoidal inputs, and flow rates not exceed specifications.

6.4.1.4 Fuel Consumption and Nominal Onboard Run Time Test

Calculate the peak power point required to drive the peak load at each 10-percent increment as follows: e.g., knowing the following valve operating conditions; (1) No load, full open valve flow conditions, and (2) Supply and return pressures, the following relationship can be assumed:

$$Q = K \sqrt{P_s - P_b - P_L}$$

Where: Q = flow rate through the full open valve

K = a dimensional constant to be derived

P_s = supply pressure psi (to valve)

P_b = back pressure psi (to load)

P_L = load pressure psi

At no load, P_L equals zero and K can be derived. Thus, an equation can be written where P_L is constant (normal case), P_b is constant, and P_s varies. Since the load on a hydraulic system in force is equal to the product of the area of the hydraulic ram piston times the pressure across the ram, the following substitution can be made:

$$P_L = \frac{F}{A} \text{ where: } A = \text{area of the piston (inches)} \\ F = \text{system load in pounds} \\ Q = K \sqrt{P_s - P_b - \frac{F}{A}}$$

Plotting Q versus F results in a parabola as shown in Figure 7. Peak power occurs at 2/3 of stall-out (P).

6.4.1.5 Operating Positions Test

Examine the oscillograph recordings to ensure that all of the oscillations are higher than the resonant frequency of the power supply and

that the output pressures for step, ramp and sinusoidal inputs, as well as flow rates, do not exceed specifications for accelerations on any axis of the centrifuge.

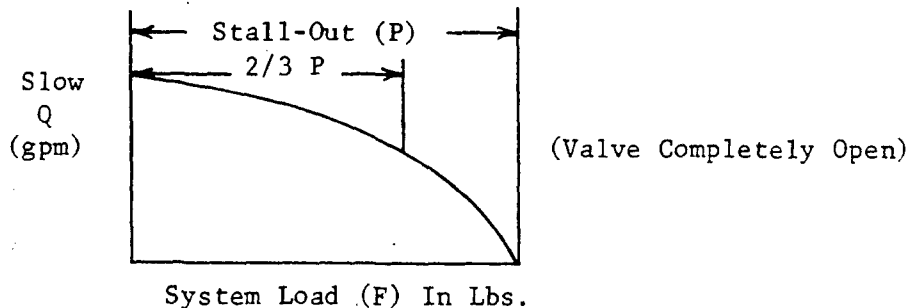


Figure 7. Typical Valve Load Curve

6.4.1.6 Resonant Spectrum Test

Check the oscillograph recordings to ensure that any resonant frequencies and amplitudes do not exceed specifications for any vibrational frequency.

6.4.1.7 Valve Seal and Operating Limits Test

The flow meter indications, as recorded on the oscillograph should not exceed the specifications for both dynamic and static internal leakage. Compute the average amount of oil leakage per missile flight. This should not exceed specifications. Determine the pressure spread (bandwidth) of the power supply by subtracting the pressure at which the valve closes from the pressure at which it opens. This should not exceed specifications.

6.4.1.8 Hydrostatic Test

Check the manufacturer's specifications to determine if yielding of any components exceed tolerances.

6.4.1.9 Nominal Heat Rise Test

Check the thermocouple recordings to ensure that the temperature rise and cooldown of the power supply does not exceed specifications.

6.4.1.10 Operating Life and Wear Resistance Test

Check the operating life cycle recordings to ensure that the operating life of the power supply is within tolerance. Compare the contaminant particle

sizes with the manufacturer's specifications for use with the servo valve to ensure that particle sizes are within tolerances.

6.4.1.11 Overspeed and Burst Speed Test

The burst point (speed mechanism failure) of the turbine driven power supply shall be compared with the manufacturer's specifications to determine if it is within tolerances.

6.4.2 Presentation

Processing of raw subtest data shall consist of organizing the data under the appropriate subtest title. All test data shall be properly marked for identification and correlation to the test item in accordance with paragraph 6.3 as a minimum.

A written report shall accompany the test data and shall consist of conclusions and recommendations drawn from test results. The test engineer's opinion concerning the success or failure of any of the functions evaluated, shall be included. In addition, equipment specifications that will serve as the model for a comparison of the actual test results should be included.

Equipment evaluation usually will be limited to comparing the actual test results to the equipment specifications and the requirements as imposed by the intended usage. The results may also be compared to data gathered from previous tests of similar equipment.

MISSILEBORNE HYDRAULIC POWER SUPPLIES

APPENDIX A

1. GENERAL

There are two general types of missileborne hydraulic power supplies, the recirculating type and the overboard-dump type. The type of power supply used determines the type of hydraulic system. The overboard-dump type is considered inefficient and is seldom encountered. Most components used in the overboard type of hydraulic system are also used in the recirculating system; therefore, this MTP emphasizes the recirculating system. However, a brief description of both systems is included to provide a better understanding of the tests.

2 OVERBOARD-DUMP SYSTEM

A diagram of a typical overboard-dump system is shown in Figure A-1.

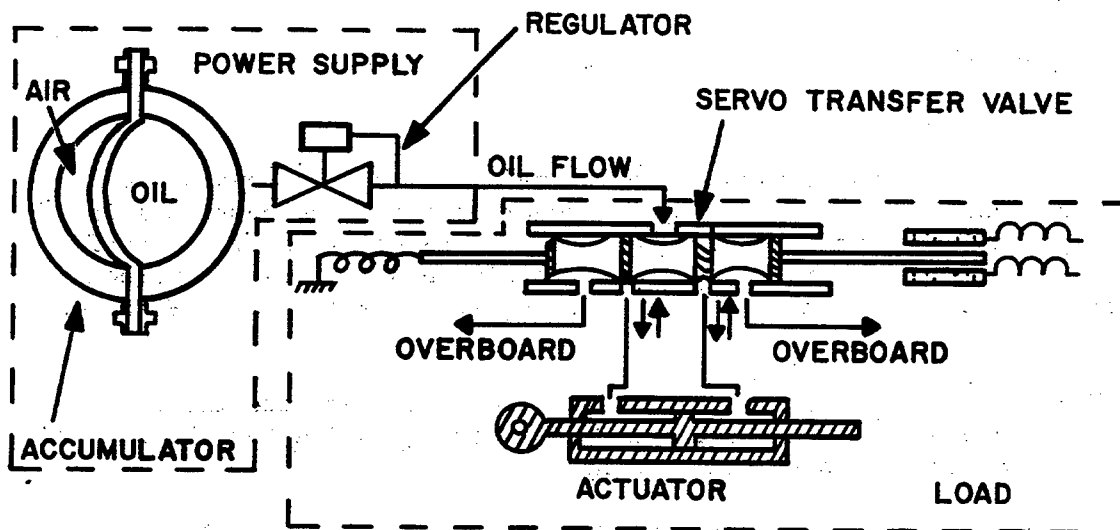


Figure A-1. Typical Overboard-Dump Power Supply System

In general, the overboard system consists of a diaphragm-type accumulator, a regulator valve, and a load consisting of the servo transfer valve and the actuator. With the servo valve in the neutral position as shown in Figure A-1, the oil is blocked from reaching the actuator. The oil pressure between the servo valve and the regulator valve holds the regulator valve closed. When the servo is activated, it will open (either to one side or the other depending on the signal) causing a drop in pressure on the right side of the regulator valve. This drop in pressure opens the regulator valve, allowing the compressed air in one compartment of the accumulator to force the oil through the

regulator and servo valves to the actuator. As the oil is forced into one side of the actuator, the oil from the other side of the actuator is dumped overboard through the servo valve.

3. RECIRCULATING SYSTEM

A diagram of a typical recirculating system is shown in Figure A-2.

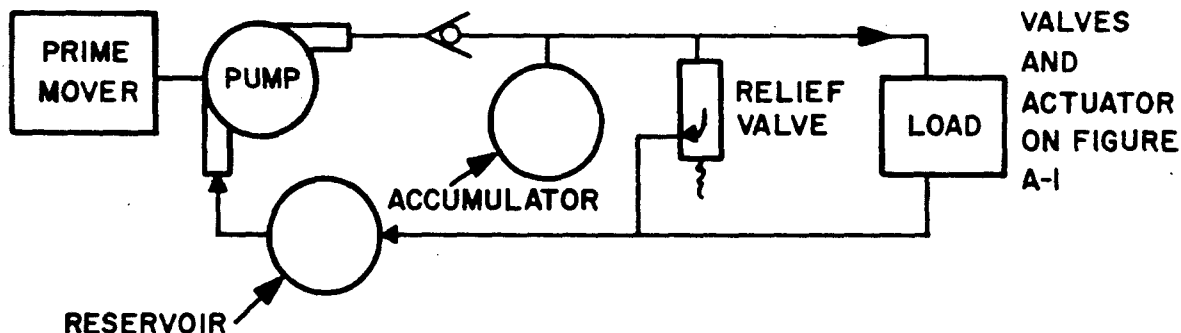


Figure A-2. Typical Recirculating Power Supply System

This type of system uses a pump to maintain constant hydraulic pressure in a closed loop. When the prime mover operates the pump, oil is forced through the check valve to the load. The load consists of a transfer valve and an actuator similar to that shown in Figure A-1, for the overboard dump system. The oil is returned from the transfer valve to the oil-storage reservoir.

The accumulator and the relief valve serve to regulate the oil pressure. The accumulator acts as an auxiliary storage place for the oil under pressure and tends to dampen pressure changes.

If the supply pressure exceeds the normal operating limits, the relief valve automatically opens to release oil from the supply line into the reservoir. When the supply pressure drops to within the normal operating range, the relief valve closes.

4. POWER-SUPPLY TEST INSTRUMENTATION

Power supplies normally are tested in laboratories especially equipped for this purpose. Consequently, the test equipment required should be available. Typical testing equipment includes a centrifuge, flow meter, thermocouples, oscillograph, timer, and heat exchanger. The flow meter is used to measure liquid movement through the system in tests such as the fuel consumption test and the power capabilities test. The timer is used to measure the duration of various operations such as starting time and operating life of the power supply. The thermocouples are used to monitor the oil temperature variations which occur

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during operation of the power supply. The oscillograph is used in conjunction with a pressure transducer to monitor and record output pressure. In dummy load operation, the heat exchanger is used to dissipate the power. A globe valve or a servo valve may be used as the dummy load for the power supply if the actual missile components are not available.